



Internal Convective Heat Transfer Effect on Iraqi Building Construction Cooling Load

Khalid Ahmed Joudi

Professor

College of Engineering-University of Baghdad

E-mail: Khalid47joudi@yahoo.com

Ali Naser Hussien

Lecturer

department of Mechanical engineering -University of Technology

E-mail: aaali_n@yahoo.com

ABSTRACT

This work involves the calculation of the cooling load in Iraqi building constructions taking in account the effect of the convective heat transfer inside the buildings. ASHRAE assumptions are compared with the Fisher and Pedersen model of estimation of internal convective heat transfer coefficient when the high rate of ventilation from ceiling inlet configuration is used. Theoretical calculation of cooling load using the Radiant Time Series Method (RTSM) is implemented on the actual tested spaces. Also the theoretical calculated cooling loads are experimentally compared by measuring the cooling load in these tested spaces. The comparison appears that using the modified Fisher and Pedersen model when large ventilation rate is used; modify the results accuracy to about 10%.

Key words: surface conductance, Iraqi building cooling load calculation.

تأثير انتقال الحرارة الداخلي بالحمل على حمل التبريد لأبنية عراقية التركيب الإنشائي

علي ناصر حسين

مدرس

قسم الهندسة الميكانيكية- الجامعة التكنولوجية

خالد أحمد جودي

أستاذ

كلية الهندسة- جامعة بغداد

الخلاصة

العمل الحالي يتضمن حساب حمل التبريد في تراكيب البناء العراقي مع الأخذ في الاعتبار تأثير انتقال الحرارة بالحمل داخل البناية. فرضية اشري فورنت مع طريقة فيشر وبدرسن في تخمين معامل انتقال الحرارة الداخلي عند استخدام معدلات عالية للتهوية لحالة تجهيز الهواء من السقف. تم احتساب حمل التبريد نظريا باستخدام طريقة السلسلة الزمنية للإشعاع (RTSM) لفضاءات اختبار حقيقية. كذلك فان حمل التبريد المحسوب نظريا تم مقارنته عمليا بقياس حمل التبريد في هذه الفضاءات. المقارنة أظهرت ان استخدام طريقة فيشر وبدرسن المعدلة لمعدلات كبيرة من التهوية, يحسن دقة النتائج لحدود تصل ل 10%.

الكلمات الرئيسية: مواصلة السطوح, حساب حمل التبريد لأبنية عراقية.



1. INTRODUCTION

The nature of air motion in the air-conditioned space is one of the important features to provide a uniform temperature, humidity, and velocity distributions to insure a comfort sense in this space. In the other hand the air conditioning equipment energy cost as a result from the variation of heat transfer by convection through the construction is influenced by the velocity and the configuration of air movement in the space. Many efforts are made in this field to estimate the essential parameters affect, to achieve the actual conception of the relation between the air movement and heat transfer.

The internal heat transfer coefficient can be combined as the conductance in the inside of the structure which is one component of overall heat transfer coefficient (U value). ASHRAE assumes that the flow of internal air near walls and roofs by buoyancy only and sometimes called “still air”, **ASHRAE, 2009** and according to this assumption the values of the inside surface conductance h_i and the resistance R_i given by ASHRAE assuming natural convection heat transfer. These values indicated in **table 1** are satisfied for many cases of air-conditioning, but the new studies of convective heat transfer in buildings, showed that for other cases, natural convection film coefficients significantly underpredict the rate of surface convective heat transfer, especially at high rate of air movement. Results of experimental convective heat transfer validation inside room found from **Ferguson, 1979**, and investigation of forced convective heat transfer coefficient at high flow rate of air ventilation introduced by **Kooi and Forch 1985**, both works appear that the convective heat transfer coefficient is impacted by the volumetric air flow rate and the air inlet temperature.

Experimental cooling load calculations for the room done by **Spitler et al. 1987** showed that the assumption of an adiabatic floor and free convection from ceiling in air conditioning spaces were incorrect. Convection coefficients correlated with twenty-seven data point by multi regression as a function of temperature difference between air and building interior surface was introduced by **Khalifa and Marshall 1990** and these coefficients are differ from ASHRAE data. **Alamdari 1991** studied the thermo-fluid analysis of the building environment using CFD model. Effect of air inlet location on the thermal comfort and inside air motion were analyzed by **Vazques et al. 1991**, and found that the temperature and flow field are greatly related to the air inlet location. A convective internal heat transfer correlations were experimentally investigated by **Spitler et al. 1991** depending on the ventilation rate by momentum number of air inlet, the correlations include roof, wall, and floor internal convective heat transfer coefficients and for wall grille air inlet.

The study of **Fisher and Pedersen, 1997** was correlated the value of the internal convective heat transfer coefficient for ceiling inlet configuration as a function of an enclosure air change rate per hour (ACH) within the range ($3 < \text{ACH} < 100$). The correlations are indicated in **table 2** for roofs, walls and floors. Fisher and Pedersen concluded that the error resulted in cooling load using ASHRAE assumption of h_i under predict the actual measuring values by more than 10%.

Djuneady 2000, Djuneady et al. 2003; Djuneady et al. 2004; Djuneady et al. 2005 simulated the air flow pattern in the air conditioned room using the coupling between the Building Energy Simulation (BES) and Computational Fluid Dynamics (CFD) (Fluent) model compared with experimental measurement; they concluded that the inlet conditions of the air have significant effect on the flow pattern.

The summary of concepts can be concluded from the above works that, the inlet air temperature, velocity, and configuration are greatly affected the indoor air movement and the convective heat transfer in the air conditioned spaces and then the accuracy of cooling load estimation. Also the adoption of ASHRAE model of Inside surface conductance h_i and the resistances R_i given by assumed natural convection heat transfer that illustrated in **Table 1** are underestimate the cooling load calculation in many cases of high rate air movement.



Therefore the suitable correlations such as Fisher and Pedersen correlations that relate the inside surface heat transfer coefficient to the air change per hour (ACH) should be adopted in cooling load calculation at high rate of ventilation, these correlations gave practical estimation to inside surface heat transfer coefficient and easy to use for ceiling inlet configuration (air supply from ceiling diffusers).

The objectives of the present work are:

1. Using Fisher and Pedersen correlation of internal convective heat transfer coefficient for ceiling inlet configuration listed in **Table 2** in calculating of cooling load for three air conditioned spaces with high rate of ventilation.
2. Repeat cooling load calculation in 1 above for the same spaces but using ASHRAE model of convective heat transfer coefficient illustrated in **Table 1**.
3. Using Radiant Time Series (RTS) method which is the latest ASHRAE method of cooling load calculation in 1 and 2 above.
4. Compare the results in 1 and 2 above with the actual experimental measurement of cooling load for the three test spaces mentioned in 1 above, to explore the accuracy of these results.

2. CALCULATION PROCEDURES IN RTS METHOD

2.1 Heat Gain Calculations in RTS Method

Wall and roof conductive heat input at the exterior at n hours ago is defined by the familiar conduction equation:

$$Q_{i,t-n} = UA(T_{e,t-n} - T_i) \quad (1)$$

where T_i is the indoor temperature and $T_{e,t-n}$ is the sol-air temperature at n hours ago and is expressed as:

$$T_{e,t-n} = T_{o,t-n} + \frac{\mu}{h_o} I_{t,t-n} - \frac{\varepsilon \Delta R(t)}{h_o} \quad (2)$$

Conductive heat gain through walls or roofs can be calculated using conductive heat inputs for the current hour and past 23 hours and conduction time series, **ASHRAE 2009**.

$$Q_t = c_{f0}Q_{i,t} + c_{f1}Q_{i,t-1} + c_{f2}Q_{i,t-2} + c_{f3}Q_{i,t-3} + \dots + c_{f23}Q_{i,t-23} \quad (3)$$

c_{f0} , c_{f1} , etc. represent the conduction time factors. Multiplying of the conduction time factors by the U value gives the periodic response factors, p_r and Eq. (3) may be rewritten as:

$$Q_t = p_{r0}A(T_{e,t} - T_i) + p_{r1}A(T_{e,t-1} - T_i) + \dots + p_{r23}A(T_{e,t-23} - T_i) \quad (4)$$

Periodic response factors, p_r can be evaluated by using Periodic Response Factor / Radiant Time Factor (PRF/RTF) Generator software published by **Iu and Fisher in 2001**. at Oklahoma state university. The program yields the conduction transfer function coefficients, the periodic response factors, and the U value, by giving the physical properties of any structure with any number of layers. These physical properties include; thickness, thermal conductivity, density, and specific heat for each layer of a homogeneous material constituting the wall or roof. For non-homogeneous materials and for air gaps and air films in and outside the structure, the equivalent thermal resistance is the input instead of other physical properties.



The heat gain from glass and the other components in the space can be calculated by reviewing **chapters 15 and 18 of ASHRAE Handbook of Fundamentals 2009**.

2.2 Conversion of Heat Gain to Cooling Load

The heat gains of all components are divided into convective and radiative heat gain portions. **Table 14 in chapter 18 of ASHRAE Handbook of Fundamentals 2009** illustrates the recommended radiative / convective splits for each component heat gain. The hourly convective portion heat gain is directly converted to hourly convective cooling load, whereas the appropriate radiant time series are applied to the hourly radiant portion heat gains to account for time delay in conversion to cooling load.

The radiant time series or Radiant Time Factors (RTF) are the series of 24 factor denoted by r in the present study and generated from heat balance procedures between interior surfaces radiant heat gain and room air for different types of structures, fenestrations, and furnishing. These factors are tabulated for specific cases, (as indicated in **table 19 and 20 in chapter 18 of ASHRAE Handbook of Fundamentals 2009**) to use them directly for the certain application instead of performing inside surface and room air heat balances. Converting the radiant portion of hourly heat gains into hourly cooling loads is accomplished by the following equation **ASHRAE 2009**:

$$Q_{clr,t} = r_0 Q_{r,t} + r_1 Q_{r,t-1} + r_2 Q_{r,t-2} + r_3 Q_{r,t-3} + \dots + r_{23} Q_{r,t-23} \quad (5)$$

The hourly radiant portion cooling load calculated in Eq. (5) above is then added to the hourly convective cooling load to obtain the total hourly cooling load for a certain component.

2.3 Inside Surface Heat Transfer Coefficient (h_i)

The convective heat transfer coefficients in Fisher and Pedersen correlations are based on a reference temperature measured in the supply air duct, which are calculated from the rate of convective heat transfer and the temperature difference between the interior surface temperature T_{si} and the supply air temperature T_s as follows (**Fisher and Pedersen 1997**):

$$h_{i(supply)} = q_i / (T_{si} - T_s) \quad (6)$$

The use of supply temperature as the reference temperature provides larger temperature differences between the surface and the air reference temperature, which enables the development of more accurate exponents and convection correlations, as proposed by **Spitler et al. , 1991a, 1991b**).

Also the internal convective heat transfer coefficient can be calculated based on the room air temperature T_i as a reference temperature as follows ,**Goldstein and Novoselac 2010**.

$$h_{i(room)} = q_i / (T_{si} - T_i) \quad (7)$$

The choice of reference temperature, as either room temperature (T_i) or air supply temperature (T_s), is dependent upon the dominant mode of convection within the room. If natural convection dominates, then room temperature is appropriate as a reference as long as the air is well mixed. However, as room air can be stratified due to the effect of buoyancy when natural convection dominates, the temperature must be taken at multiple points vertically from floor to ceiling, and averaged for an accurate reading. Whereas the choice of air supply temperature (T_s) as a reference temperature is more appropriate when forced convection dominates ,**Goldstein and Novoselac 2010**.



For building energy simulation programs or load calculation methods that utilize the room temperature as the reference, the correlations developed as a function of supply air temperature can easily be converted to correlations that utilize room air temperature as follows, **Goldstein and Novoselac 2010**.

$$h_{i(room)} = h_{i(supply)} * \left(\frac{T_{si} - T_s}{T_{si} - T_i} \right) \quad (8)$$

3. EXPERIMENTAL VERIFICATION OF RTSM

Figs. 1, 2, and 3 show the schematic floor plans of the three test spaces and the distribution of temperature sensor that measured the inside and outside temperature. These figures also illustrate the semi-conditioned space that neighbored to the test spaces and have temperatures higher than the test spaces. The heat gain resulted due to this temperature difference denoted by due T.D. The test spaces are 24 hr air-conditioned and have ceiling air inlet diffusers in the medical city in Baghdad (33.3° N latitude and 44.4° E longitude), the three test spaces were as follows:

1. Statistics office in the maintenance building, which will be called space A.
2. Pharmacy store in the pharmacy department buildings, named space B.
3. Meeting room in burns care building designated space C.

Table 3 illustrates the shape of diffusers and the average air velocity across them, whereas the construction component details of three spaces are listed in **Table 4a** for the external construction of each space that exposed to external heat sources, and **Table 4b** for the internal construction of each space that exposed to Temperature Difference T.D. only.

The air change per hour of ventilation of each space has ceiling inlet configuration and the corresponding inside heat transfer coefficients h_i are indicated in **Table 5**. These values of h_i (T_s) are calculated based on Fisher and Pedersen model using the supply air temperature as a reference value. But h_i (T_i) that calculated based on average room air temperature as a reference value is required. Therefore Eq. (8) is used for this purpose. A shaded boarded value in **Table 5** will be used as a modified surface resistance values.

Periodic response factors (PRFs) that are needed to calculate the heat gain of the roofs and walls included R_i of ASHRAE assumption and PRFs of roofs of spaces A, and B, and the ceiling and walls of space C according to the new modified R_i shaded boarded values in **Table 5**. PRFs are calculated by inserting the thermal properties of the building materials in addition to the surface resistances in the dialog box of PRF/RTF Generator program mentioned in section 2.1.

Thus, the theoretical cooling load can be calculated by apply Eqs. (2, 4, and 5). And the values of rs are selected from **Table 19 in chapter 18 of ASHRAE Handbook of Fundamentals 2009** for heavy weight, no carpet and 10% of glass to wall ratio.

The experimental verification of the calculated cooling load was accomplished by measuring the average indoor air temperature, the supply air temperature and the flow rate. The sensible heat extraction was calculated as **ASHRAE 2009**:

$$Q_{s,h} = \dot{m}_a * c_p * (T_i - T_s) \quad (9)$$

$$\text{where } \dot{m}_a = \rho \dot{V}_s / RT_s \quad (10a)$$

$$\dot{V}_s = \nu_a * A_c \quad (10b)$$

$$\text{and } c_p = 1.006 + 1.840 * w_s \quad (10c)$$



where the specific heat of dry air and water vapor were taken as 1.006, and 1.840 kJ/kg.K respectively for the range of air conditioning temperatures and w_s is the moisture content. The approximated value of c_p is equal to 1.012 kJ/kg.K.

The heat extraction rate is equal to the cooling load if the indoor temperature of the space is constant. The latent load inside the space was zero for no occupancy.

4. RESULTS AND DISCUSSION

Cooling load calculations by ASHRAE and modified Fisher and Pedersen convective heat transfer models appear that the average increase in cooling load of each hour calculated by modified model is about 15.5 W (about 7%) for the roof of space A as shown in **Fig. 4**. This value of increasing is low relative to the value of ventilation ratio which is 20.7 ACH and 7.5 °C temperature differences between internal room surface and air supply. The low effect of the inside surface conductance on the cooling load value of the roof of space A is due to the high overall resistance and the thick material of this roof which weaken the h_i effect.

For the roof of space B, **Fig. 5** shows that the raising in cooling load of each hour is about 90 W (about 16.6%). This significant raising resulting from the difference in inside surface conductance of ASHRAE model compared with that of modified model. According to ASHRAE model inside surface conductance (h_i) of the metal sheet suspended ceiling of space B is 2.1W/m²K (notes under **Table 1**) because of this metal surface is reflective and has low emittance value, where h_i is 15.44 W/m²K according to modified model at 13.19 air changes per hour and the difference between internal room surface and air supply temperature of 8 °C.

Space C of 18.77 air change per hour and 9 °C surface temperature over than supply air temperature is exposed to heat flow from the ceiling and all the external and internal walls. The augmentation of cooling load components of each hour due to the modifying of interior heat transfer coefficient model were: ceiling/ 39 W (about 17.9%), NE shaded wall/ 18 W (about 6.23%), NW wall/ 33.2 W (about 6.29%), and internal walls/ 41W (about 9.4%). The increase of modified h_i of the ceiling resulted in a significant increase in cooling load. The percentage of increasing the cooling load of internal walls is higher than that of the external walls because of the difference in overall resistance between them. The increase in thickness of the layers of building materials increases the overall resistance of the roof or the wall and reduces the variation effects in surface conductance. The overall increase in cooling load of each hour is 131.2 W (about 10%). **Fig. 6** shows the cooling load components that calculated by both ASHRAE and modified model of estimating h_i .

Figs. 7 to 9 show the variation of total cooling load of all components of three spaces which are calculated theoretically based on baseline ASHRAE model and modified Fisher and Pedersen model in addition to a measured heat extraction rate from the three tested spaces. On these figures the variation of outdoor temperature, the average room air temperature, and supply air temperature are graphed. Also the daily average indoor temperature T_i which is used in theoretical calculation and assumed as a constant temperature is written on figures.

The average theoretical cooling loads which are calculated by base (ASHRAE) and modified Fisher and Pedersen model and the average measured heat extraction are mentioned on each figure denoted by LCBav, LCMav and QMav respectively. These represent the daily average values that calculated by summing the values for each hour along 24 hours and divided by 24.

The percentage difference ratios between measured and theoretical base cooling load and between measured and theoretical modified cooling load are calculated as: ((LCBav - QMav)/QMav)% and ((LCMav - QMav)/QMav)% respectively. These percentage difference ratios are used to discuss the results of **Figs. 7 to 9** in the following.

Fig. 7 shows the theoretical cooling load for all components calculated by ASHRAE baseline model and modified model in addition to measured cooling load for space A. The difference



between the average measured value and the average calculated value in this space is (-8.6%) compared with modified model and (-9.3%) compared with ASHRAE model. These values represent the underestimation of the calculated cooling load compared to that measured.

Fig. 8 shows the baseline and modified model theoretical cooling load of space B in addition to measured cooling load. The difference between the average measured heat extracted and the average theoretical load is (-0.45%) in comparison with modified cooling load and (-2.8%) with ASHRAE model.

For space C, the modified and baseline theoretical models cooling load compared with the measured cooling load is shown in **Fig. 9**. The modified model that take in account the effect of modified h_i of ceiling and walls has the average modified result higher than average baseline result by about 10 %. Whereas the average measured values of heat extracted are higher than average theoretical results. The error values are about (-9.7%) for modified model and (-19.8%) for ASHRAE model.

5. CONCLUSIONS

The following conclusions are found from the present work and pertinent for the variation of the internal surface conductance and its effect on cooling load calculations:

1. A 20.7 air changes per hour with 7.5 °C temperature differences between internal room surface and air supply increases the internal heat transfer coefficient of the non-reflective roof surface according to modified model by about 14.6 W/m²K more than ASHRAE model which in turn increases the heat gain value of heavy weight concrete roof with insulation and roofing material by about 7%.
2. A 13.19 air changes per hour with the difference between internal room surface and air supply temperature by 8 °C increases the internal heat transfer coefficient of the reflective roof surface according to modified model by about 13.9 W/m²K higher than ASHRAE model. And then increases the heat gain value of heavy weight concrete roof with insulation and roofing material painted steel sheet suspension ceiling by about 16.6%.
3. The rate of air change per hour of 18.77 and 9 °C surface temperature over than supply air temperature magnify the internal surface conductance by about 24.5 W/m²K of non- reflective roof surface and 3.6 W/m²K of wall surfaces more than ASHRAE model. And thus increases the heat gain by about 17.9% of heavy weight concrete roof with insulation and roofing material, and 6.3% and 9.4% of double row perforated brick with stone sheathing of external wall and hollow block interior partitions respectively.
4. The increasing in cooling load calculated by modified model lessen the underestimation of the overall calculated cooling load values depending on ASHRAE model from the actual measured values by 0.7% , 2.35%, and 10.1% as in cases of spaces A, B, and C respectively.

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NOMENCLATURE

A	area	m^2	
c_p	specific heat of air	kJ/kgK	
c_f	conduction time factor		
h_i, h_o	inside, outside heat transfer coefficient	W/m^2K	
I	solar radiation	W/m^2	
m_a	air mass flow rate	kg/s	
p	atmospheric pressure	pa	
p_r	periodic response factor	W/m^2K	
Q	heat	W	
R	gas constant of air	kJ/kgK	
R_i	internal surface thermal resistance	m^2K/W	



ΔR the difference between the long wave radiation incident on the surface from the sky and surroundings, and the radiation emitted by a black body at the outdoor air temperature W/m^2

r radiant time factor

T temperature $^{\circ}C$

t time sec

U overall heat transfer coefficient W/m^2K

v_a air supply velocity m/s

V_s air supply volume flow rate m^3/s

w_s moisture content kg_{water}/kg_{air}

Greek Symbols

e emittance of the surface

m absorptivity of the surface

Subscripts

a air

c cross sectional (diffuser area)

e sol-air (Temperature)

i indoor

o outdoor

s supply

t total (solar radiation), time (others)

Abbreviations

ACH Air Change per Hour

due T.D due temperature difference

LCBav average Calculated Baseline Load W

LCMav average Calculated Modified Load W

PRF Periodic Response Factor W/m^2K

QMav average Measured Load W

RTS Radiant Time Series

RTSM Radiant Time Series Method

tot. calc.base total cooling load calculated according to base (ASHRAE) model W

tot. calc.Mod. total cooling load calculated according to modified model W

Table 1. Surface conductances and resistances for air, **ASHRAE 2009.**

Position of surface (assume still air)	Direction of heat flow	Nonreflective surfaces		Reflective surfaces			
		Emittance, $\epsilon=0.90$		Emittance, $\epsilon=0.20$		Emittance, $\epsilon=0.05$	
		h_i W/m^2K	R_i m^2K/W	h_i W/m^2K	R_i m^2K/W	h_i W/m^2K	R_i m^2K/W
Horizontal	Upward	9.26	0.11	5.17	0.19	4.32	0.2
Sloping at 45°	Upward	9.09	0.11	5.00	0.20	4.15	0.24
Vertical	Horizontal	8.29	0.12	4.20	0.24	3.35	0.30
Sloping at 45°	Downward	7.50	0.13	3.41	0.29	2.56	0.39
Horizontal	Downward	6.13	0.16	2.10	0.48	1.25	0.80

* Surface emittance of ordinary building materials is 0.9 and for metals and metal paint between 0.05 and 0.5

Table 2. Heat transfer coefficients for ceiling inlet configuration (air supply from ceiling diffuser) ,Fisher and Pedersen 1997.

Surface type	Correlation
Walls	$h = 0.19 \cdot ACH^{0.8}$ (W/m ² K)
Floor	$h = 0.13 \cdot ACH^{0.8}$ (W/m ² K)
Ceiling	$h = 0.49 \cdot ACH^{0.8}$ (W/m ² K)

Table 3. Diffuser shapes, dimensions, and air flow measuring data.

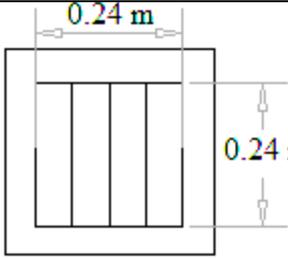
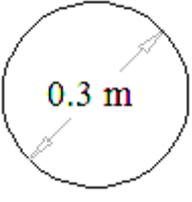
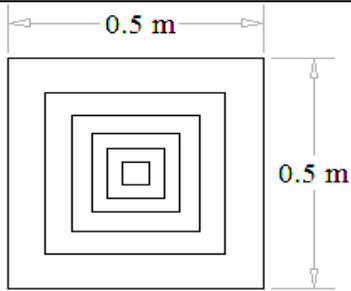
Space	A	B	C
Average velocity m/s	6	7.133	1
Diffuser shapes			

Table 4a. External wall, roof and floor construction details of tested spaces.

Spaces		Constructions (from outside to inside)	Direction and area m ²
A	Wall	External air conductance +3 cm of cement plaster +30 cm thermo-stone +1.5cm juss plaster +1 cm gypsum plaster + internal air conductance	NE=8.32 NW=15.05
	Roof	External air conductance +4 cm of cement shtyger +5 cm of sand +1cm of felt and membrane +5 cm of sty-rubber + 15 cm of high density concrete + air gap +acoustic tiles in suspended ceiling + internal air conductance	22.25
B	Wall	External air conductance +2.5 cm of cement plaster +20 cm hollow block +1.5cm juss plaster +1 cm gypsum plaster + internal air conductance	SW=34.65 SE=18
	Roof	External air conductance +4 cm of cement shtyger +5 cm of sand +1cm of felt and membrane +5 cm of sty-rubber + 20 cm of high density concrete + air gap + metal plates in suspended ceiling + internal air conductance	51
C	Wall	External air conductance +5 cm of helan stone+ 5 cm of cement mortor +24 cm perforated brick +1.5cm juss plaster +1 cm gypsum plaster + internal air conductance	SW=17.2 SE=14.74



Table 4b. Internal wall, roof and floor construction details of tested spaces.

Spaces		Constructions (from outside to inside)	Area m ²
A	Wall	Internal air conductance +1 cm gypsum plaster +1.5cm juss plaster +20 cm hollow block +1.5cm juss plaster +1 cm gypsum plaster + internal air conductance	7.92
	floor	Internal air conductance +20 cm of high density concrete+3cm cement mortar+2.5cm mozaek tile +internal air conductance	22.25
B	Wall	Internal air conductance +2mm of steel sheet +air gap+ 2mm of steel sheet + internal air conductance	40.635
C	walls	Internal air conductance +1 cm gypsum plaster +1.5cm juss plaster +20 cm hollow block +1.5cm juss plaster +1 cm gypsum plaster + internal air conductance	20.87
	ceiling	Internal air conductance +2.5cm granite tile+3cm cement mortar +30 cm of high density concrete+ air gap +1.5cm suspended ceiling +internal air conductance	17.76
	door	Internal air conductance+5cm wood+ Internal air conductance	1.7

Table 5. Interior conductance according to Fisher and Pedersen model for the tested spaces.

spaces	ACH	T _s °C	T _i °C	Surface	T _{si} °C	h _i (T _s) W/m ² K	h _i (T _i) W/m ² K	R _i (T _i) m ² K/W
A	20.7	17	22.5	Ceiling	24.5	5.53	20.74	0.048
				Walls	24.5	2.145	8	0.12
				floor	24	1.47	6.86	0.146
B	13.19	17	23	Ceiling	25	3.86	15.44	0.065
				Walls	25	1.5	6	0.16
				floor	24	1.023	7.16	0.14
C	18.77	15.5	23	Ceiling	24.5	5.12	30.7	0.0325
				Walls	24.5	1.98	11.88	0.084
				floor	23.5	1.36	21.76	0.046

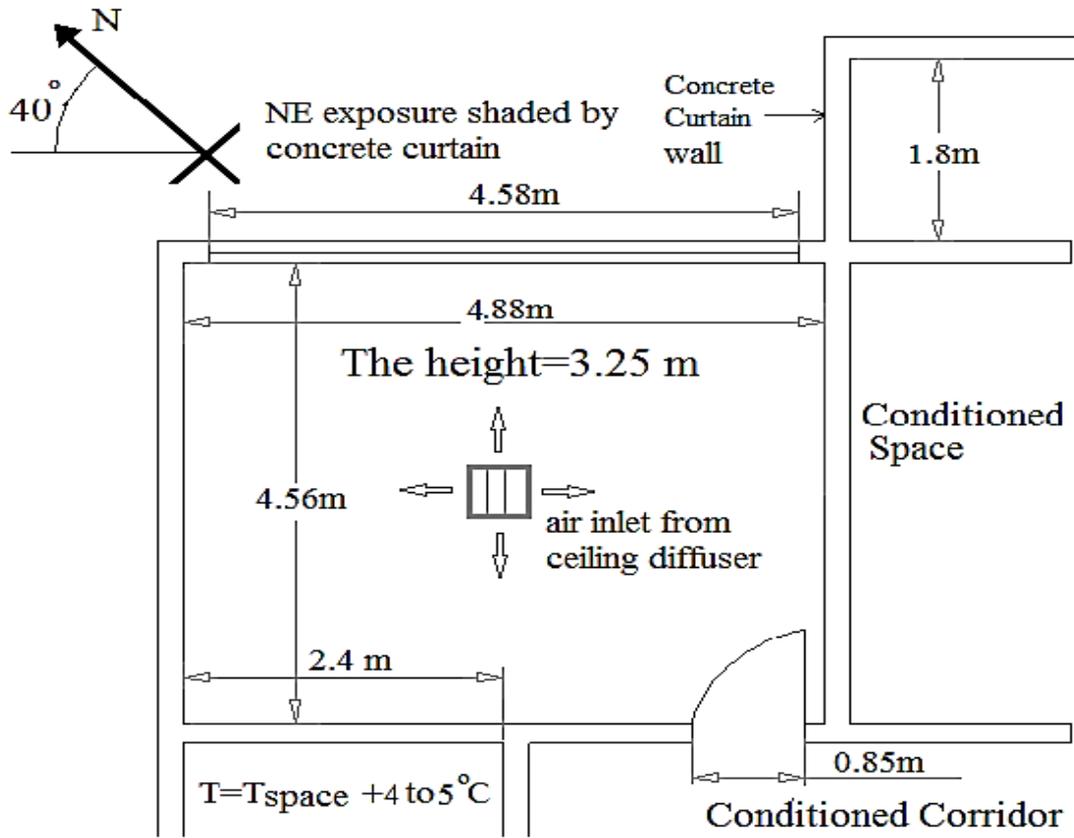


Figure 1. Schematic floor plan of tested space A.

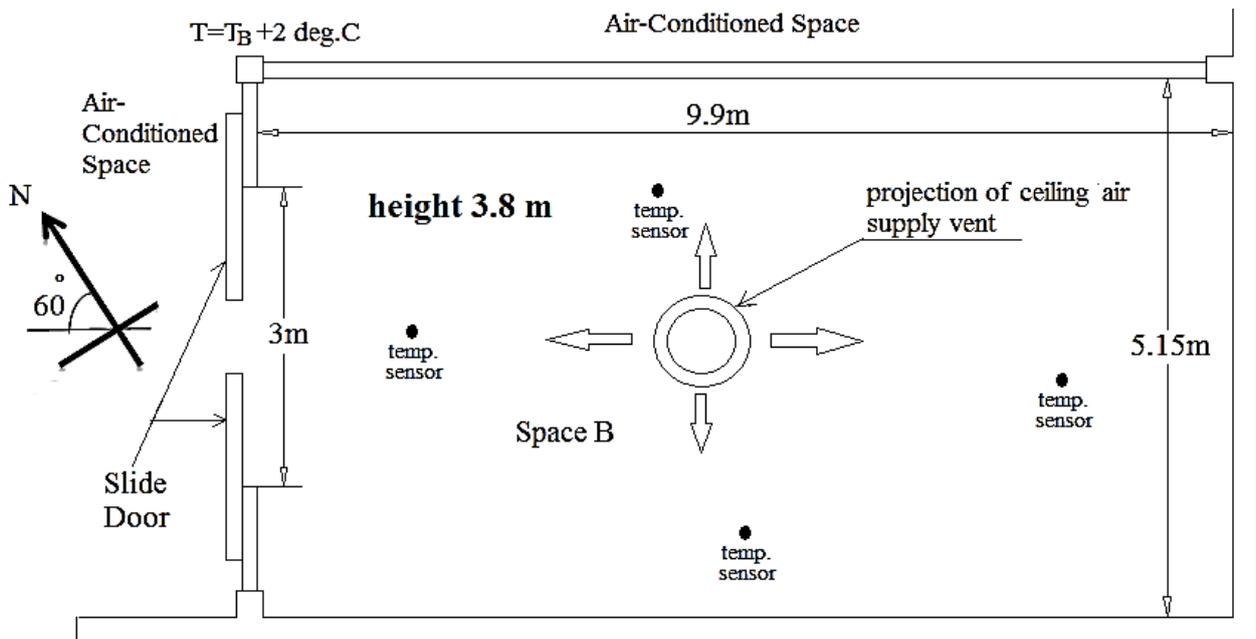


Figure 2. Schematic floor plan of space B .

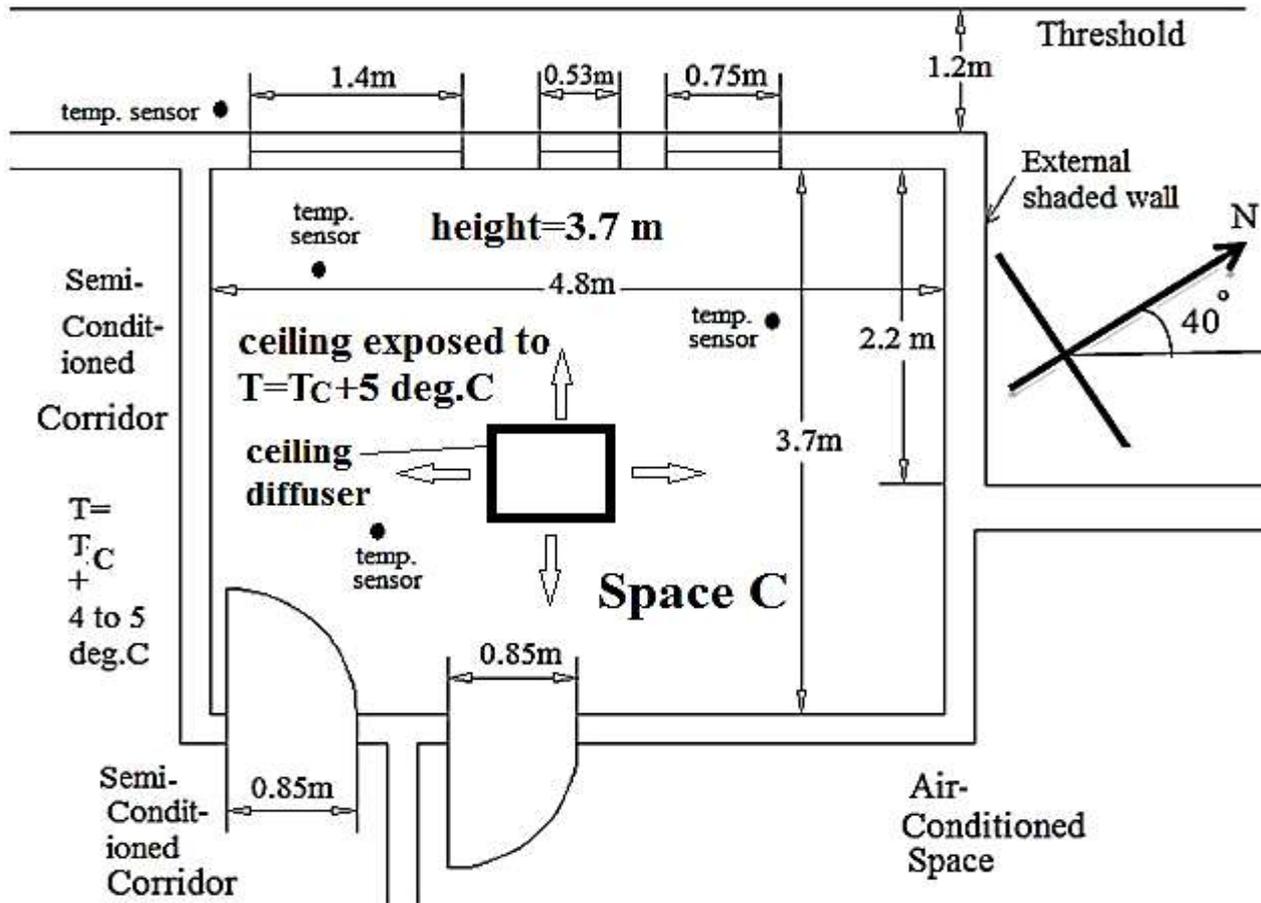


Figure 3. Schematic floor plan of space C.

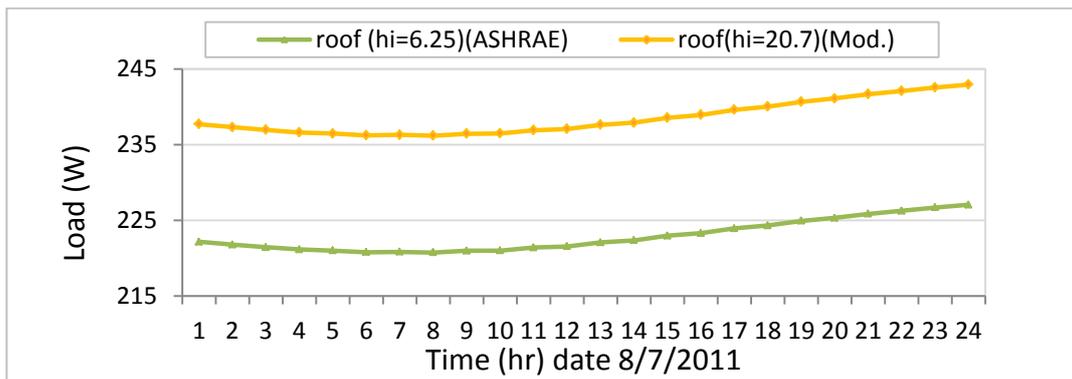


Figure 4. The effect of h_i model on the cooling load of the roof of space A on 8th July 2011.

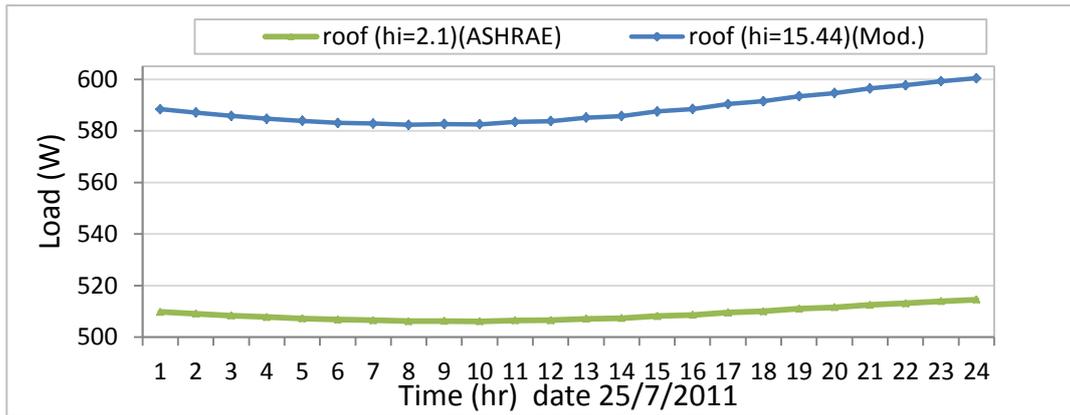


Figure 5. The effect of h_i model on the cooling load of roof of space B on 25th July 2011.

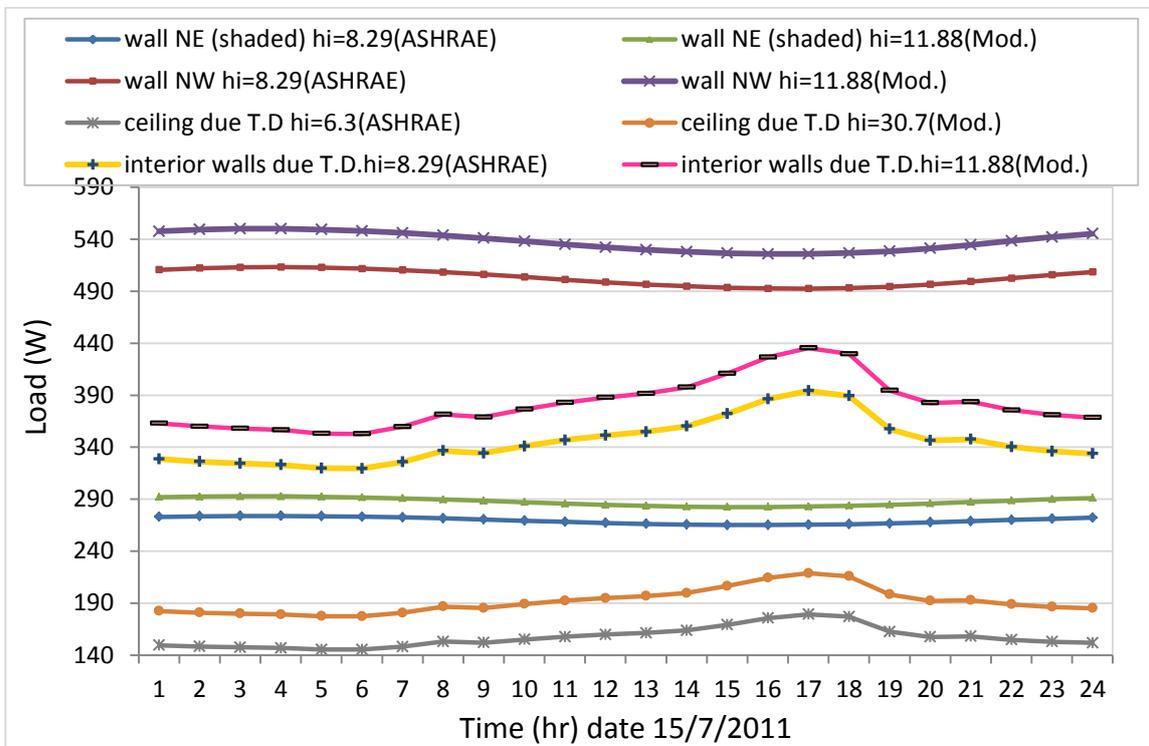


Figure 6. The effect of h_i model on the cooling load of the ceiling and walls of space C on 15th July 2011.

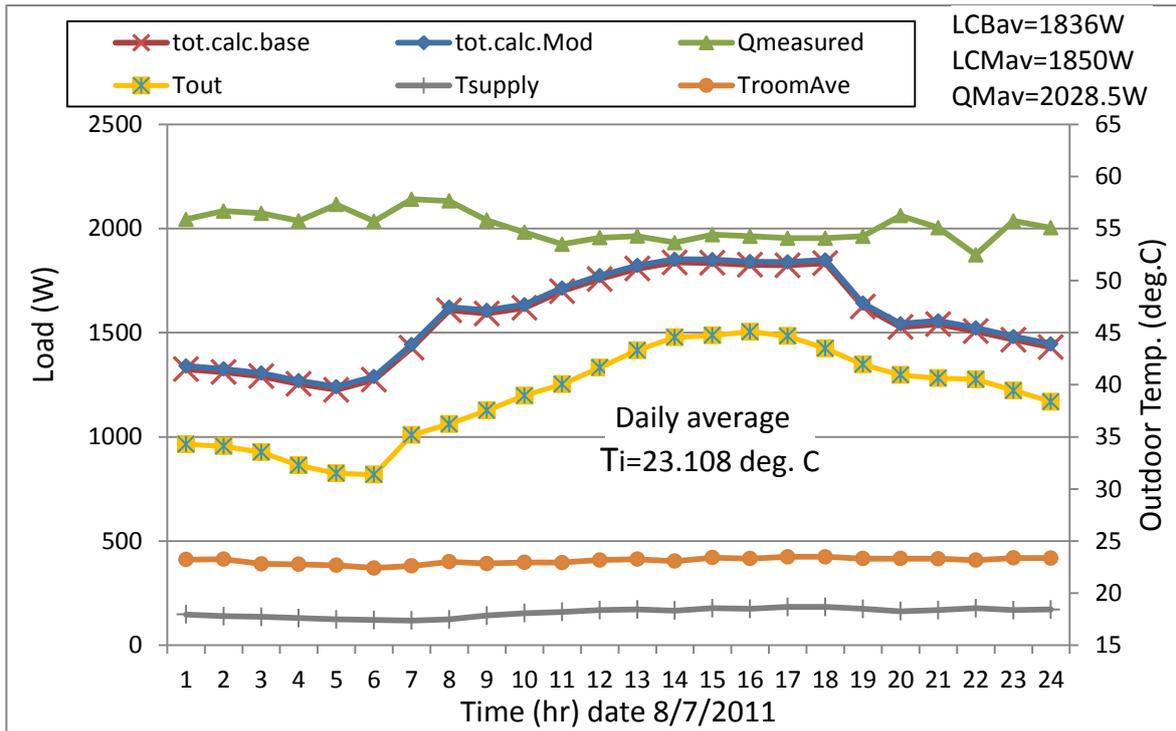


Figure 7. Cooling load comparison for the calculated baseline and modified model with the measured load of space A on 8th July 2011.

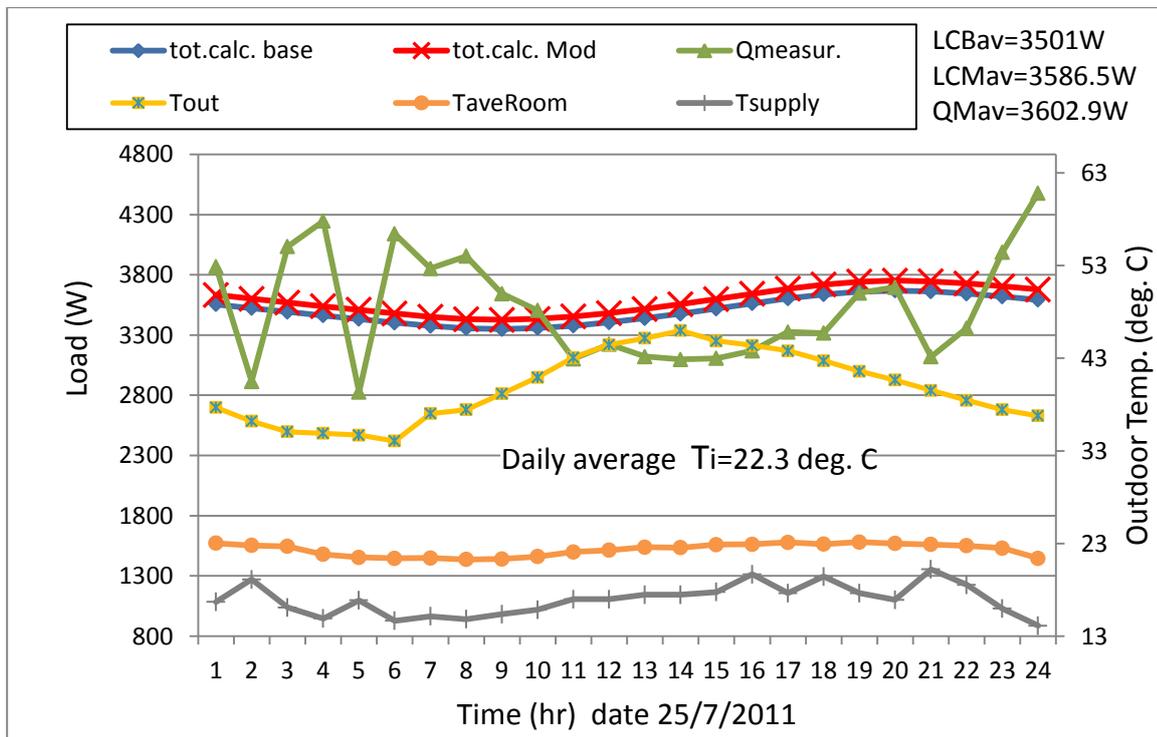


Figure 8. Cooling load comparison for the calculated base and modified model with the measured load of space B on 25th July 2011.

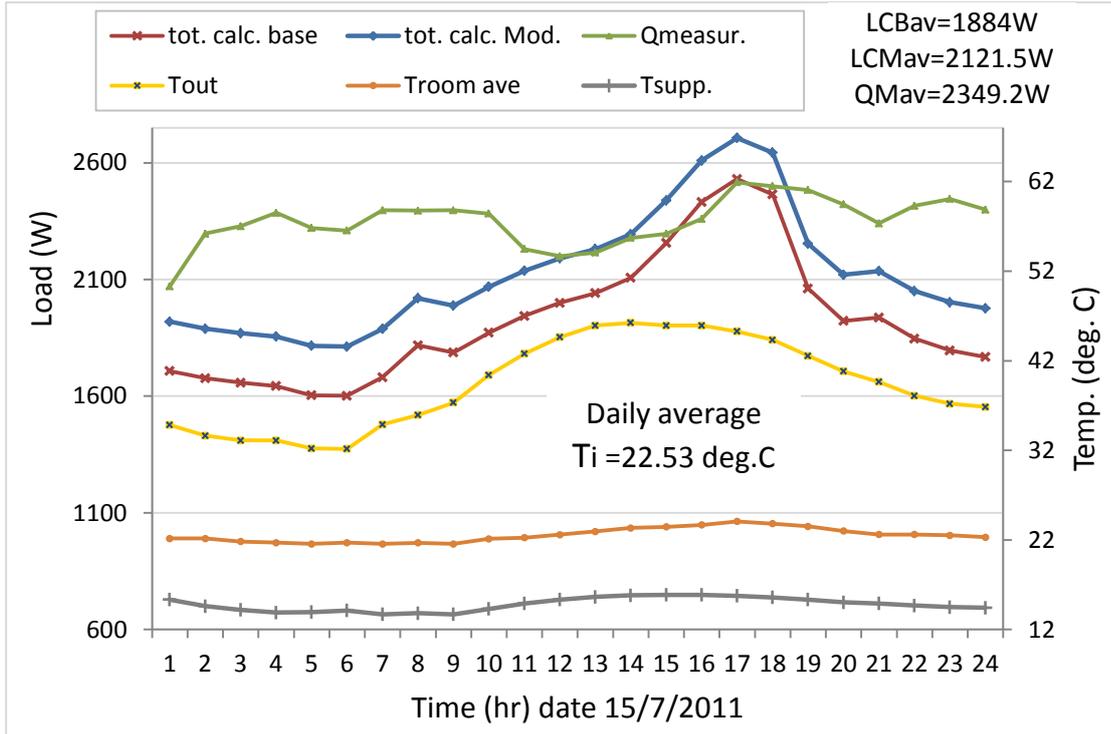


Figure 9. Cooling load comparison for the calculated base and modified model with the measured load of space C on 15th July 2011.